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Characteristics of a locally fabricated N_2-laser system

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Abstract : A superradiant N_2-laser system has been fabricated using the Blumlein circuit arrangement Laser power is very much sensitive to the gas pressure and peaks at 17 5 torr inside the discharge tube It has also been observed that the laser power increases with the increase of applied voltage and reaches at a saturation value so long as the discharge is controlled by the high voltage pulse generator. Further increase of applied voltage produces self-starting discharge in the tube causing stoppage of laser output and damage to the Cu-coated epoxy sheet condenser. When air from the atmosphere is used in the discharge tube, the laser power becomes sensitive to the moisture content of air and as a result, it decreases with the increase of humidity The laser power increases approximately by 30% when instead of air commercial grade N_2-gas is used. The approximated N_2-laser power at 7.27 KV AC and 77.2 torr tube pressure with the repetition rate fixed at about three pulses per second was measured to be 6 15 × 10^{-6} watt when spark switching device worked at 110.2 cm (Hg) N_2-gas pressure

Keywords : N_2-laser system, characteristics, Blumlein circuit

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The nitrogen laser is important as a nanosecond pulsed source of intense ultraviolet radiation and as a suitable pump light source for dye lasers. It has also been extensively used in studying, the interaction of light with atoms, molecules and biological specimens. For many of these applications, one needs high power nitrogen lasers together with good pulse reproducibility. Heard [1] was the first to discover the laser action from electronic transition of nitrogen in the second positive band. Leonard [2] and Gerry [3] used transverse excitation of the N_2-laser tube to obtain high power output. Many workers reported different designs to obtain high power output which lies between 10 KW–1 MW [4–8].

Low pressure transversely excited N_2-laser designed by us has the following characteristics (Figure 1).

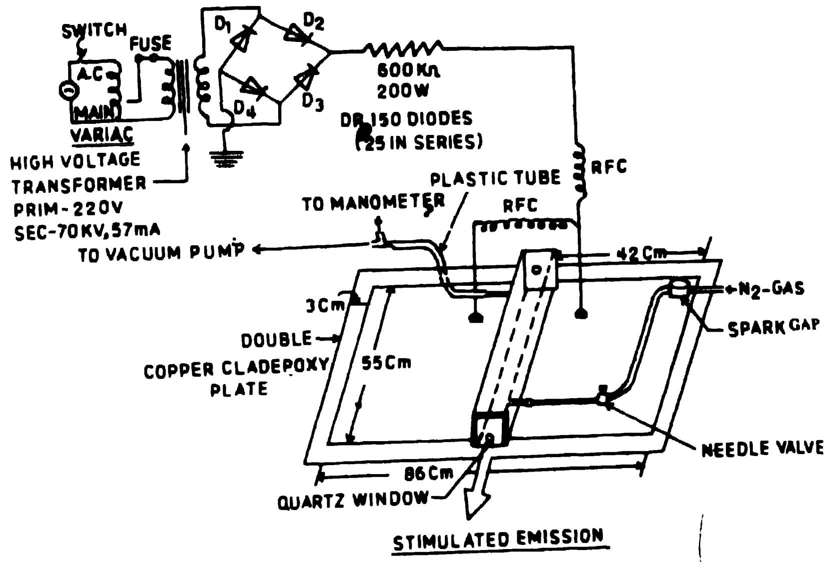

Figure 1. Schematic diagram of Blumlein type transversely excited N_2-laser

(i) The thickness of the copper epoxy sheet is 0.8 mm which being small helps in increasing the condenser capacity and reduces the working voltage for the same laser output. The measured breakdown voltage of the sheet is 10.5 kV AC. Two parallel plate condensers of capacity 18.57 nF each are made from the copper clad epoxy sheet (55 cm × 42 cm × 0.8 mm) of dielectric constant 3.64.

(ii) A bridge rectifier made of twenty five DR-150 diodes in each of its four branches, converts high AC voltage into DC voltage. The maximum value of DC output is about 12 kV.

(iii) The triggered spark gap has been developed with two brass discs of diameter 6.3 cm and thickness 20 mm each. The spark is produced by a scooter plug connected to a pulse generator. The scooter plug has been developed to carry radial spark rather than axial spark by cutting the bent portion of its electrodes. The axial separation between the electrodes of the spark gap has been kept at 1.5 mm. The spark causes one condenser to discharge paving the way for the discharge of the other through electrodes of N_2-laser tube.

(iv) N_2-laser cavity consists of two aluminium electrodes fixed with perspex plates of length 54 cm each. The laser electrodes form a wedge having larger electrode separation at the far end than at the near end. The increase in this separation is 1 mm in 54 cm length of the channel electrode with the average separation being nearly 1 cm. One of the electrodes has a rounded surface whereas the other knife-edge shaped.

Since nitrogen laser is ultraviolet (337.1 nm) in nature it was observed by its blue fluorescence on a piece of white paper. The laser radiation is made incident on the slit of the quartz spectrograph (R. Fuess Berlin-Steglitz 5082, Germany). The slit width was kept at 0.379 mm. The wavelength scale-over the drum was set right. A photomultiplier tube (PMT) (Oriel Corporation, 77344) was fitted in the focal plane of the Camera of the spectrograph. It was further connected to a readout arrangement (Oriel Detection system, model 7070). The exit slit in front of the PMT was adjusted 0.5 mm to allow the full laser spectral beam to come out and fall on the PMT. The reading over readout arrangement gives the relative laser intensity. The gas pressure inside the discharge tube is a very sensitive parameter for laser emission in a given laser system. The gas pressure of the tube was monitored with the help of a mercury manometer made up of a hard glass U-tube. The measured threshold lasing voltage for laser action was 5.096 kV and the discharge at 7.53 kV became uncontrolled when spark plug was maintained at the atmospheric pressure (75.1 cm Hg). In this position, the minimum and the maximum gas pressures in the laser channel for laser action were observed to be 10 and 44 torr respectively.

The laser output increases with the increase of applied AC voltage (Figure 2) and saturates at 7.5 kV when the tube pressure is kept constant (15 torr). The reason behind this observation is that higher applied voltage pushes larger number of molecules in the excited laser level of nitrogen $(C^3\pi_u)$ producing larger laser output. The saturation in output is observed when most of the molecules in the laser channel get excited to this level.

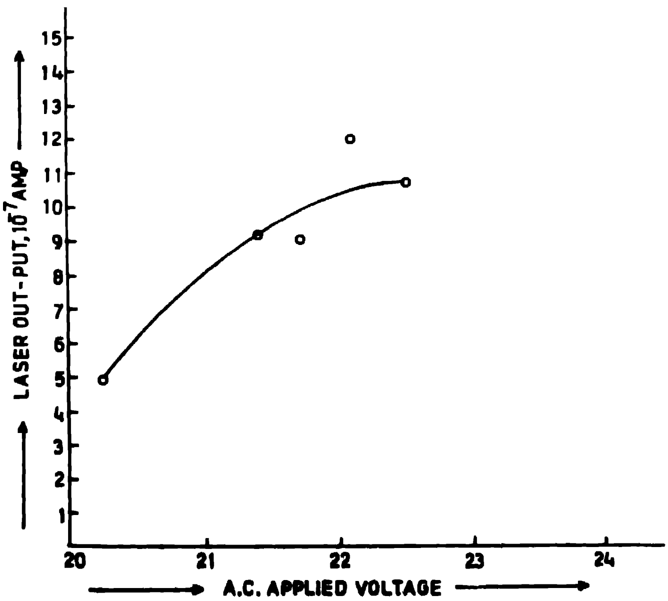

Figure 2. AC applied voltage *vs* laser power output graph.

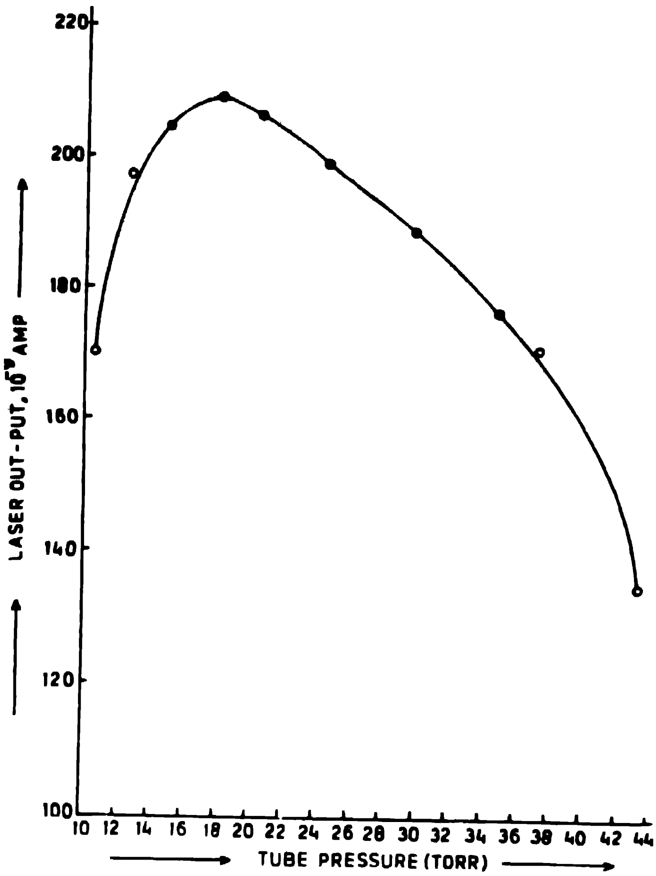

Figure 3. Pressure *vs* laser power output graph.

The variation of laser output (PMT reading) with respect to the tube pressure has been further studied (Figure 3). It is observed that the laser power is maximum at a tube pressure of 17.5 torr.

The curve (Figure 3) shows that rise in laser power is faster than the fall, as the gas pressure in the discharge tube increases. This laser power seems to be related to the mean free path of electrons inside the gas. When this mean free path is such that electrons acquire

Table 1. Mean free path of electron at different gas pressure.

Tube pressure in torr	10.5	12.5	15.5	17.5	20.5	24.5	29.5
Mean free path of electron (in 10^{-3} cm)	6.09	5.12	4.13	3.66	3.12	2.61	2.17

sufficient kinetic energy (in the electric field between the two electrodes) to excite N_2 molecules in the energy state $C^3\pi_u$ through collision, the laser output becomes large. The maximum probability of such collisions produces maximum laser output. This collision probability is related to the gas pressure inside the discharge tube through the number of N_2-molecules per c.c. When the pressure decreases, the mean free path increases (Table 1) but the collision probability decreases at a faster rate and vice-versa.

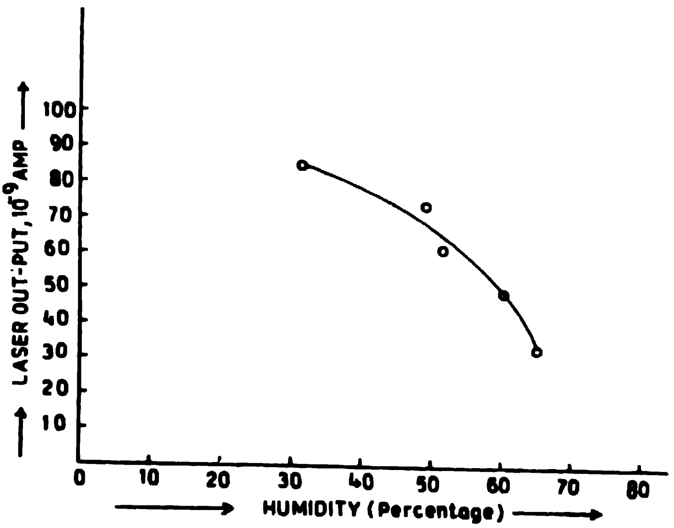

Figure 4. Humidity *vs* laser power output graph.

Initially, the laser was operative with air in the discharge tube while the gas pressure at the spark plug was kept at atmospheric pressure. When a pressure difference between the spark plug and the discharge tube was created with a needle valve, it was observed that the moisture content of air had an effect over the laser output which decreases with the increase of humidity (Figure 4). The reason was the fall in resistivity of discharging gas with the rise of humidity. The increase in conductivity reduces the discharge voltage which prevents high voltage high current fast discharge, resulting into fall of laser output. There is about 30% increase in the laser output if commercial grade N_2-gas is used as a laser active material. The same gas is used to raise the pressure at the spark plug. This raises the upper limit of gas pressure inside the laser tube from 44 torr to above 77 torr.

The value of laser power obtained from the commercial grade N_2-gas was approximated by comparing it with that of a known He–Ne laser source. This was possible because the PMT used was nearly equally sensitive in the range 250 nm–800 nm. This range of wavelength covered both the wavelengths, those of N_2-laser (337.1 nm) and He–Ne laser (632.8 nm, 5 m watt, Oriel Corporation, model 79272). The approximated N_2-laser power at 7.27 kV AC and 77.2 torr tube pressure with the repetition rate fixed at about three pulses per second was measured to be 6.15×10^{-6} watt, when the optimum gas pressure at the spark plug was 110.2 cm. of Hg.

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